Treatment-Effect Identification Without Parallel paths

An illustration in the case of Objective 1-Hainaut/Belgium, 1994-2006

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Abstract

Imagine a region that has a lower income per head than the rest of the territory, and becomes eligible for a generous EU-funded transfer programme (the treatment). The evaluation of the effectiveness of such a policy can rest on a difference-in-differences analysis (*DiD*); which in essence consists of comparing the income-level handicap before and after the treatment. Imagine that *DiD* shows that the handicap has not diminished, or even that it has risen. Most observers would conclude to the inefficiency of the policy. The point we raise in this paper is that second thoughts are needed, because *DiD* rests heavily on the validity of a key assumption: parallel paths in the absence of treatment. Without EU money the outcome difference between the treated and the controls should be time-invariant; so that any statistically significant change of that difference can be ascribed to the treatment. Parallel paths seems a priori unrealistic in the context of old industrial regions, as one of the reasons they become eligible for treatment is that their income-level handicap is on the rise. Also, from a methodological point of view, when more than one pre-treatment period is available in the data, the parallel-paths assumption can easily be abandoned in favour of more flexible assumptions as to the relative dynamics of treated vs. control entities. This paper illustrates the relevance this approach in the case of Objective 1-Hainaut; an EU-funded transfer policy implemented between 1994 and 2006 in Hainaut, the most economically-deprived province of Belgium; a former bastion of the country's industrial revolution that has endured decades of decline.

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1. Introduction

This paper deals with how to properly evaluate the impact of policies like Objective 1-Hainaut. At its core lies a methodological proposal. But let us start with a few words about Objective 1 and the province of Hainaut in Belgium.

Objective 1-Hainaut is an example of an European-Union (EU)-funded transfer policy aimed at helping European regions reduce their socio-economic handicap. The policies have a relatively old history. The underpining idea was present in the preamble to the Treaty of Rome in 1957, and has been further emphasised in the 1980s with the entry of Greece, Portugal and Spain. In 1987, with the Single European Act, the EU received explicit competence for undertaking a regional policy aimed at ensuring convergence. Over the decades, a growing political concern for the so-called "regional problem" has meant that a considerable – and increasing – amount of resources has been spent in an attempt to mitigate regional income disparities.[1] Since the mid-1980s, the importance of EU development/convergence policies has not ceased to increase. In budgetary terms, the policies have grown from representing a mere 10% of the EU budget and 0.09% of the EU-15 GDP in 1980, to more than one third of the budget and around 0.37% of the EU GDP as an average of the period 1998-2001 (Rodríguez-Pose & Fratesi, 2003). The policies have become, after the Common Agricultural Policy (CAP), the second largest policy area in the EU. Also, every recent step towards greater economic integration at EU level has been accompanied by measures aimed at supporting financially the lagging countries or regions. For instance, the decision in the Maastricht reform to create the Single European Currency that was tied in with the establishment of the Cohesion Fund in order to alleviate the burdens that transition to EMU would impose on the less developed territories.

After the reform, more than two thirds of all Structural Fund expenditure has been concentrated in the so-called Objective 1 regions. These are territories whose GDP per capita, measured in

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[1] The European Commission's focus on regional disparities has been paralleled by a renewed academic interest – both theoretical and empirical – in the economic analysis of growth and (non) convergence. From the work of Romer (1986), (1990) and Lucas (1988), a growing body of literature, known as 'new growth theories', has started to question the optimistic predictions of the traditional neoclassical model laid out by Solow (1956), which leaves little or no role to regional/convergence policy.

purchasing power standards (pps), is less than 75% of the EU average. In the 1990s, the list comprised 64 NUT2 regions[2] (Tondl, 2007), one of them being Hainaut in Wallonia/Belgium (Figure 1). The Belgian province benefited for Objective 1 money between 1994 and 1999. And from 2000 to 2006 it also benefited from the "phasing out" programme.

Yet, despite their rising macroeconomic importance, questions are being raised about the capacity of European development policies, in general, and of policies targeted at Objective 1 regions in particular, to achieve greater economic and social cohesion and to reduce income gaps. These questions are fundamentally based on rather mixed evidence about convergence following implementation (Magrini, 1999). In that context, it is a bit surprising that there are very few *ex post* economic evaluation studies[3] of the monetary benefits of Objective 1. More precisely, there are very few papers answering questions such as “what would be the level of income per head in region *X* had it not benefited from Objective 1 money ? ». Along the same line, and in contrast with what economists and econometricians have done to evaluate other types of policy interventions (higher minimum wages, employment subsidies, active labour-market or social policies…), very little work has been done using microdata, in a quasi-experimental setting, to evaluate the effectiveness of Objective 1 (or other EU policies aimed fostering convergence across regions or countries).

In a sense, this paper aims at filling that void. This said, at its core, lies a methodological discussion of what can (or cannot) be achieved within the Difference-in-Differences paradigm (*DiD*). This is statistical technique commonly used in microeconometrics (Angrist & Krueger, 1999) that attempts to mimic an experimental research design using observational study data, by studying the differential effect of a treatment on a 'treatment group' versus a 'control group' in a (quasi) natural experiment. It calculates the effect of a treatment (e.g. Objective 1) on an outcome (e.g. income per capita) by comparing *i)* the average change over time in the outcome variable for the treatment group (e.g. Hainaut), to *ii)* the average change over time for the control group (e.g. rest of Belgium). Key to this paper is the idea that one should go beyond the canonical *DiD* model, if data permit.

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[2] Nomenclature of Units for Territorial Statistics (NUTS) is a geocode standard for referencing the subdivisions of countries for statistical purposes. The standard is developed and regulated by the EU, and thus only covers the member states of the EU in detail.

[3] There are several macroeconomic models that have been used to assess the *potential* impact of EU funds on economic growth (e.g. HERMIN model). All these models estimate positive growth effects from cohesion spending, but their size changes depending on the theoretical assumptions upon which the model is based.

This paper capitalises on and extends an idea initially proposed by Mora & Reggio (2012). The latter authors refer to the canonical *DiD* model – and the parallel-paths assumption underpinning identification – as $DD_{[1]}/Parallel_{[1]}$. In the absence of treatment (and in particular before its inception) the (average) outcome-level difference between the treated and the control is time-invariant; so that the observation any change of that level difference after treatment can be ascribed to treatment. When data contain 2 or more pre-treatment periods, Mora & Reggio (2012) suggest allowing for $Parallel_{[2]}$, $Parallel_{[3]}$, and even higher degrees of parallelism. The general idea is that of diverging paths in the absence of treatment stemming from (pre-treatment) acceleration[4] differences, surge[5] differences or even higher-order differences…. Why still talk of "Parallel-something" if there is divergence? Because the identification idea remains that at the heart of the canonical $DD_{[1]}$ model: in the absence of treatment, the differences between these accelerations or surges (…) should be time-invariant. Thus the key idea remains that of a Difference-in-Differences between before and after treatment. But while $DD_{[1]}$ focuses on the evolution of outcome-level differences, $DD_{[2]}$ tracks the evolution of outcome-acceleration differences; and $DD_{[3]}$ that of outcome-surge differences;

Also, the efficiency criteria associated to these different degrees of parallelism vary dramatically. And this matters a lot for policy interpretation of results. In the context of a deprived region receiving financial aid, using $DD_{[1]}/Parallel_{[1]}$ as a treatment-evaluation method means that the objective is to achieve a significant reduction of the initial income-***level*** handicap of that region. Under $DD_{[2]}/Parallel_{[2]}$, the requirements are intrinsically milder. Efficiency exists as soon as one detects a reduction of the pre-treatment income-***acceleration (or growth rate)*** handicap. Note also that there is no paradox in $DD_{[1]}$ results being negative, while those delivered by $DD_{[2]}$ are positive. That simply means that the initial income-level handicap has risen, but less than it would had the acceleration handicap not been reduced (see Figure 2 for an illustration). By contrast, if even $DD_{[2]}$ shows no significant gains, then it means that the policy has not been not very effective at all; as it has not even been able to slow down the divergence process (i.e. reduce the pre-treatment acceleration/growth rate handicap).

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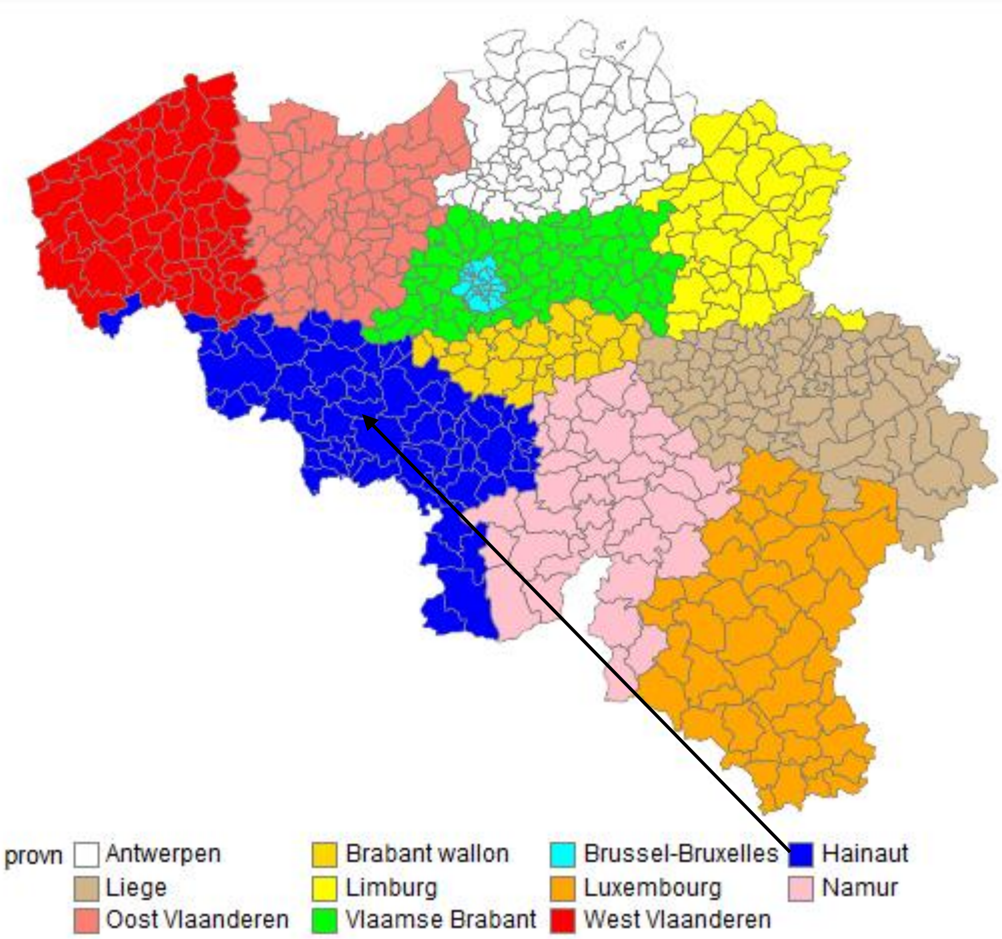
[4] Or growth rates in a more economic context.

[5] The rate of change of acceleration/growth rate; that is, the derivative of acceleration/growth rate with respect to time

In the case of Objective 1-Hainaut, using per head income data and the rest of Wallonia or Belgium as a control group, our $DD_{[1]}$ results suggest a negative impact. But the analysis of pre-treatment data clearly show that $Parallel_{[1]}$ (constant income-level handicap in the absence of treatment) did not hold before inception. We rather find statistically significant evidence of $Parallel_{[2]}$ (constant acceleration/growth rate handicap before 1994). This is thus the assumption we retain for identifying Objective 1's true impact. And when doing so, results change considerably, as our $DD_{[2]}$ estimates are positive and statistically significant. This is supportive of the idea that Objective 1 reduced the acceleration/growth rate handicap that affected Hainaut before 1994. In the absence of this correction, the income-level handicap increment – the one typically measured by $DD_{[1]}$ – would have been larger. Over the year 2010 horizon, we find that Hainaut experienced a rise of its income-level handicap compared to the rest of Belgium of 426 euros. But we find a statistically significant $DD_{[2]}$ of 491 euros. This means is that in the absence of thie acceleration handicap (positive) correction; the income-level handicap rise would have been of 426 + 491 euros.

The rest of the paper is divided into five sections. Section 1 exposes analytically the $DD_{[1]}/Parallel_{[1]}$, $DD_{[2]}/Parallel_{[2]}$… $DD_{[q]}/Parallel_{[q]}$ sequence, and how they can be implemented using simple OLS estimates. Section 2 briefly discusses Objective 1-Hainaut ; its particularities and the calendar of its implementation. Section 3 presents the dataset used in this paper and some descriptive statistics. Section 4 presents the main estimation results. Section 5 concludes.

Figure 1 – Hainaut and other Belgian provinces (+ the 589 municipalities)



1. Beyond parallel 1

The key results presented in the paper (Section 4) rest on the estimation of difference-in-differences (*DiD*) models. One of the key originalities of the paper is the way the traditional *DiD* analysis is augmented to allow for non-parallel paths before treatment; and thus for the treatment to consists not just of a reduction of the income *level* handicap between Hainaut and the rest of Belgium or Wallonia, but also – and more modestly – a reduction of the pre-treatment income *acceleration [or growth rate]* difference/handicap, or even a reduction of higher-order differences.

The canonical $DD_{[1]}$ model exploits 2 periods (one before and one after the treatment) to identify the effect of treatment. But its ability to correctly identify that effect rests on the validity of the parallel-paths (i.e. $Parallel_{[1]}$) assumption. In our data, we have the chance to have many pre-treatment observations. This allows for two things.

First, to verify the validity of the *Parallel*$_{[1]}$ assumption. And we will clearly see that it is violated as the income difference between Hainaut and the rest of Belgium (rest of Wallonia) was on the rise before 1994.

Second, and more importantly, the fact that we observe both the treated and the control territories several times before the treatment allows us to assess the propensity of Hainaut to accelerate/growth at slower pace than and the rest of Belgium/Wallonia before treatment [and also to assess the validity what amounts to a *Parallel*$_{[2]}$ assumption i.e. constant acceleration/growth rate handicap before treatment] and determine whether treatment has positively contributed to reducing the initial acceleration/growth rate handicap.

Algebraically, all $DD_{[p]}$, where $p=1, 2...N$ designates the degree of parallelism underpinning identification, can be estimated using the OLS-estimated coefficients of an equation like [1]. Consider 3 periods (t-1, t the two periods before treatment, and $t+1$ the first period after treatment) and the corresponding time dummies (I_t) with indicator dummy D designating the treated ($D=1$) vs control ($D=0$) entities. Outcome in $t+1$ writes

$$Y_{t+1}= \gamma + \gamma_t I_t+ \gamma_{t+1} I_{t+1} + \gamma^D D + \gamma^D_t D.\ I_t + \gamma^D_{t+1} D.\ I_{t+1} \qquad [1.]$$

The usual $DD_{[1]}$/*Parallel*$_{[1]}$ estimator, covering the immediately before-and-after treatment period t and $t+1$ - as estimated by researchers who only possess these two periods of observation - is $DD_{[1]}^{t+1}=(\gamma^D_{t+1}+\gamma^D)- (\gamma^D_t +\gamma^D)=\gamma^D_{t+1}- \gamma^D_t$. where the $t+1$ subscript indicates that we evaluate treatment 1 year after its inception (the generalisation to $t+s$ follows). But, when two pre-treatment periods are available, one can also compute the equivalent estimator to capture what happened between t and t-1 i.e. $DD_{[1]}^t= \gamma^D_t+\gamma^D-\gamma^D=\gamma^D_t$. If *Parallel*$_{[1]}$ holds, then this estimator should deliver a value that his not statistically different from zero. The first implication of possessing 2 periods of observation is thus that researchers can test the validity of the *Parallel*$_{[1]}$ before treatment and assess the capacity of $DD_{[1]}^{t+1}$ to properly identify the effect of treatment. If $DD_{[1]}^t=\gamma^D_t$ is statistically different from zero, then treated and control trends diverge before treatment (Figure 2a,b). In fact $\gamma^D_t \neq 0$ captures the presence of pre-treatment acceleration (or growth rate) differences. On Figure 2, we imagine the case where, before treatment, the treated entity (e.g. Hainaut) not only suffers from an income level handicap ($\gamma^D < 0$) but also suffers from and acceleration/growth rate handicap (each period, the level handicap rises at a rate $\gamma^{D}{}_{t}$). If that is the case, $DD_{[1]}^{t+1}= \gamma^{D}{}_{t+1}- \gamma^{D}{}_{t}$. cannot properly identify the impact of treatment. In the case illustrated on Figure 2, it wrongly points at a negative effect of treatment ; while the truth is that treatment contributed to reducing the output handicap by lowering the control group's acceleration/growth rate handicap (i.e. the red dashed line is a notch steeper than the solid one

For the case depicted on Figure 2a,b, the proper identification of the treatment effect should rather rests on *Parallel*$_{[2]}$ in the absence of treatment, and on the ability of the *DD* estimator to measure a deviation from *Parallel*$_{[2]}$ once treatment begins. This can be achieved by

$$DD_{[2]}^{t+1}= \gamma^{D}+\gamma^{D}t_{+1}-[\gamma^{D}+\gamma^{D}{}_{t} + DD[1]^{t}]= \gamma^{D}{}_{t+1}- 2\gamma^{D}{}_{t} \qquad [2.]$$

$T=t-1,t, t+1$

or, said differently, the difference between *i)* the observed $t+1$ outcome level handicap[6] i.e. $\gamma^{D}{}_{t+1}$ and *ii)* the expected one ($\gamma^{D}{}_{t} + DD_{[1]}{}^{t}$) ; where the first term $\gamma^{D}{}_{t}$ is the level handicap in t and the second one the one-period contribution of acceleration/growth rate difference (observed between t and t-1 ; and captured by $DD_{[1]}{}^{t}=\gamma^{D}{}_{t}$)

The $DD_{[2]}{}^{t+1}$ estimator can be generalised to account for the possibility that treatment lasts more than one period or, alternatively, that it takes several periods to deliver significant effects. In $t+s$;$s\geq 1$, the difference between the observed level handicap and the expected one is

$$DD_{[2]}^{t+s}= \gamma^{D}{}_{t+s}- [\gamma^{D}{}_{t} +s.\ DD[1]^{t}]= \gamma^{D}{}_{t+s}- (1+s)\gamma^{D}{}_{t} \qquad [3.]$$

$T=t-1,t, t+s$

A further generalisation is to assume that *Parallel*$_{[2]}$ (i.e. constant acceleration/growth rate difference) might not correctly describe the relative dynamics of treated and controls in the absence of treatment. If data contain 3 pre-treatment observations, researchers may observe that *Parallel*$_{[2]}$ does not hold before treatment and then resort to *Parallel*$_{[3]}$ (i.e. time-invariant surge differences in the absence of treatment) to properly identify the effect of treatment

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[6] Net of the initial handicap observed in t-1 : γ^{D}

$$\begin{aligned} DD_{[3]}^{t+s} &= \gamma^D_{t+s} - [\gamma^D_t + s.(DD[1]^t + DD[2]^t)] = \\ &\gamma^D_{t+s} - [\gamma^D_t + s.((\gamma^D_t - \gamma^D_{t-1}) + \gamma^D_t - 2\gamma^D_{t-1})] = \\ &\gamma^D_{t+s} - [\gamma^D_t + s.(2\gamma^D_t - 3\gamma^D_{t-1}) = \gamma^D_{t+s}] = \\ &\gamma^D_{t+s} - \gamma^D_t - s.(2\gamma^D_t - 3\gamma^D_{t-1}) = \gamma^D_{t+s} - (1+s)\gamma^D_t - s.(\gamma^D_t - 3\gamma^D_{t-1}) \end{aligned} \qquad [4.]$$

$T=t-2,t-1,t,\ t+s$

The ultimate generalisation is to assume $Parallel_{[p=q]}$. Note that the degree of parallelism $p=1 \ldots N$, corresponds to the number of pre-treatment periods that are needed for the model to be estimated. As to post-treatment, the minimal requirement is to possess one observation at horizon $t+s\ ;\ s \geq 1$. The treatment effect can then be estimated using the OLS-estimated coefficients of the $q-1$ interaction terms $D.I_t$ of the following equation

$$\begin{aligned} Y_{t+s} &= \gamma + \left[\sum_{\pi=t-q+1}^{t} \gamma_\pi \ I_\pi\right]^{min(1,q-1)} + \gamma_{t+s} I_{t+s} + \gamma^D D + \\ &\left[\sum_{\pi=t-q+1}^{t} \gamma_\pi^D \ D.I_\pi\right]^{min(1,q-1)} + \gamma^D_{t+s} D.\ I_{t+s} \end{aligned} \qquad [5.]$$

$T=t-q, \ldots., t,\ t+s$

It is in fact is equal to

$$DD_{[q]}^{t+s} = \gamma^D_{t+s} - \left(\gamma^{D\ min(1,q-1)}_t + s.\sum_{\tau=1}^{q-1} DD[\tau]^t\right) \qquad [6.]$$

where $DD[\tau]^t = (1-L)^\tau \gamma^D_t$ with L the lag operator[7]

Note that when $q=1$, the minimum data requirement is to have 2 periods of observation ($T=t,\ t+s$). Also $min(1,q-1) = 0$ and equation [5] boils down to the canonical *DD* equation

$$Y_{t+s} = \gamma + \gamma_{t+s} I_{t+s} + \gamma^D D + \gamma^D_{t+s} D.\ I_{t+s} \qquad [7.]$$

and equation [6] simplifies to

$$DD_{[1]}^{t+s} = \gamma^D_{t+s} \qquad [8.]$$

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[7] $(1-L)X_t = X_t - X_{t-1}\ ;\ (1-L)^2 X_t = (1-L)(X_t - X_{t-1}) = (X_t - X_{t-1}) - (X_{t-1} - X_{t-2})\ ;\ \ldots$

where the treatment effect is presumably captured coefficient the interaction variable of the afterXtreated dummy interaction variable.

Figure 2a – The inadequacy of traditional difference-in-(level) differences estimator ($DD_{[1]}$) in the presence of non-parallel paths

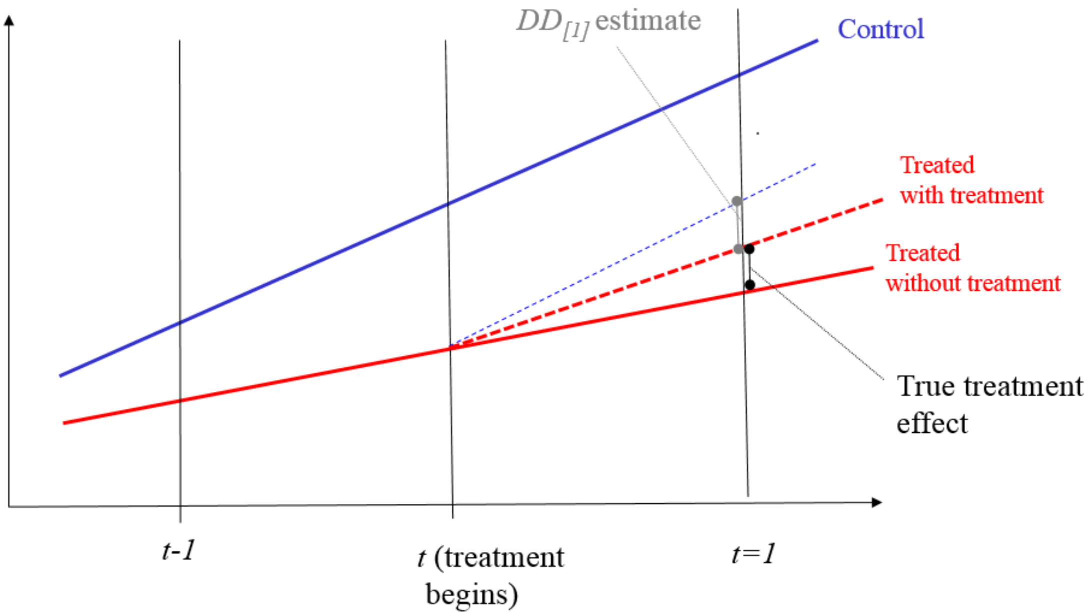
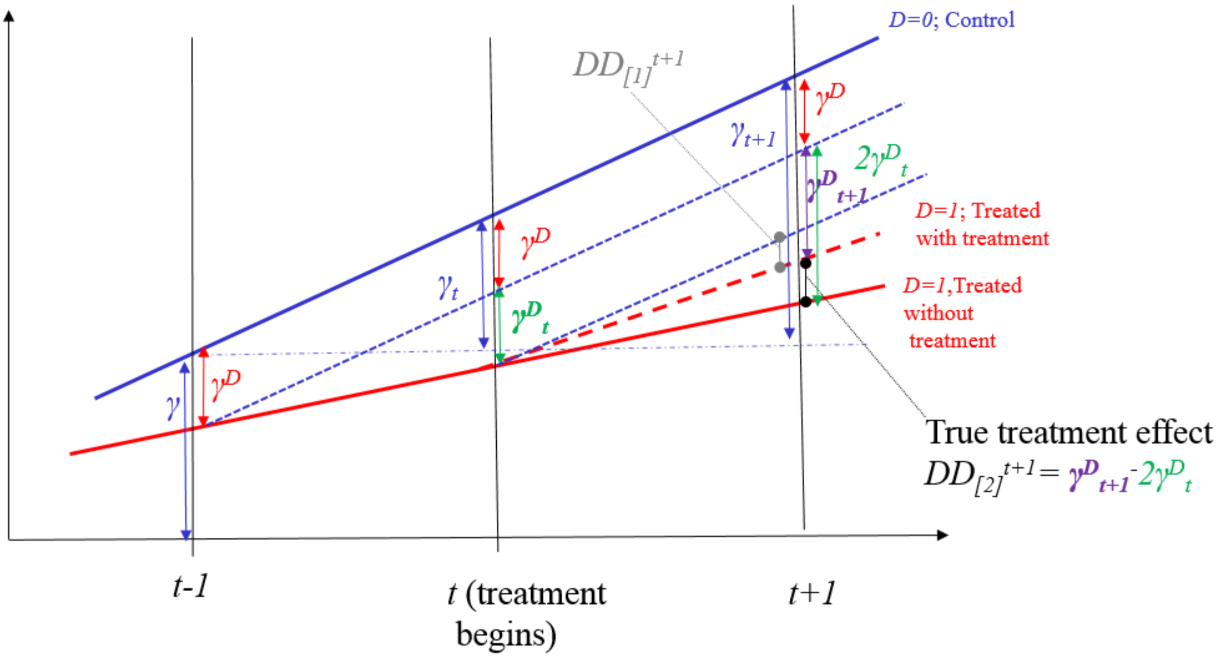


Figure 2b – How difference-in-(acceleration)differences ($DD_{[2]}$/$Parallel_{[2]}$) can cope with non-parallel paths

$$Y_{t+1} = \gamma + \gamma_t I_t + \gamma_{t+1} I_{t+1} + \gamma^D D + \gamma^D_t D.I_t + \gamma^D_{t+1} D.I_{t+1}$$



2 Objective 1: Hainaut vs…

Hainaut (Figure 1) is a province (one of the NUTS2 EU regions) situated in French-Speaking Wallonia, forming the south of Belgium. It is one of the most economically deprived parts of the country. At its heart lies the large the city of Charleroi: a former bastion of the country's industrial revolution that has since endured decades of decline. In 1993, Hainaut was retained on the list of EU regions eligible to Objective 1. It benefited from that EU programme from 1994 to 2006. This was in spite of its GPD per capita of 77.3% of the EU reference being superior to the 75% threshold. Interestingly in the context of this paper, the Commission considered that, on top of being relatively close to the selection criteria, the province was suffering from a substantial deterioration of its economic and social situation. In other words, there was a negative income acceleration/growth rate gap, in addition to pure income level gap; and also a severe problem of underemployment.

During the first phase (1994-1999), the sums injected in the province's economy by both the EU and Belgian authorities (due to mandatory national co-financing) were relatively high at 2.43 billion EUROS (1994 nominal), representing a bit less than 5% of the province's GDP for each of the year ranging from 1994 to 1999.[8] Priorities ascribed to Objective 1-Hainaut were *i)* the improvement of the competitiveness of enterprises (e.g.; R& D credits) (1/3 of the total), *ii)* the attractiveness of the region (e.g. through cleaning up of old industrial sites) (1/4 of total), *iii)* prospects for tourism and research facilities (1/5 each) (IMF, 2003).

It is also worth underlying that the treatment in the form of financial support from the EU did not stopped completely in 1999. Beyond that point, the province benefited from the EU's Objective "phasing out" programme (2000-2006), representing a total injection of 2.22 billion EUROS (2000 nominal).

As to the control entities, we use three: the province of Liège, the rest of Wallonia and the rest of

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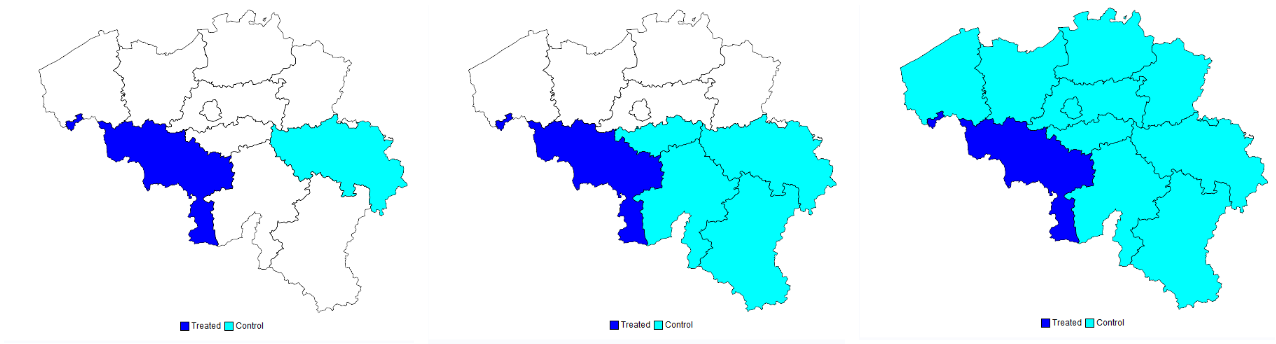
[8] Statistics Belgium estimates Hainaut's GDP (income perspective) to be of 9.497 billion in 1994 EUROS. Objective 1, over the period 1994-1999, represents a cumulative sum of 2,430 billion in 1994 EUROS injected in the province' economy. Per year, this amounts to a push equal to 4.9 % of Hainaut's GDP.

Belgium (Figure 3). A priori, we expected the province of Liège to be the best control territory for the implementation of the canonical $DD_{[1]}$ model. That province has many things in common with Hainaut. Although its economy was fairing better in 1993 judging by the level of income (Figure 4), the province has also suffered from systematic deindustrialisation over the past decades. We had doubts about the relevance of $Parallel_{[1]}$ for the rest of Wallonia as a whole, and even more about the rest of Belgium that includes the dynamic Flemish provinces. Results largely confirm our intuition. They show that if Liège and Hainaut where approximately on parallel paths before 1994, that was not at all the case of Hainaut and the two larger control entities.

Figure 3 – Hainaut vs Liège, rest of Wallonia or Belgium



3 Data, descriptive statistics

The data used in this paper consist of taxable net[9] income data (all earnings[10] – professional and other deductible expenses) per head, provided by Statistics Belgium. These are available for each of Belgium's 589 municipality (Figure 1) from 1977 to 2013; with many years before 1994 which is the year Objective 1 treatment started (Figure 3); and also after 1999 (end of the first phase of Objective 1) or 2006 (end of the phasing-out period). Readily available information about the number of inhabitants at municipal level was used as weighting factor in order to capture trends that are representative at a more aggregated level; e.g.; the entirety of Hainaut (our treated entity) (Table 1). The advantage of this outcome variable is that it is reliable: time series on taxable

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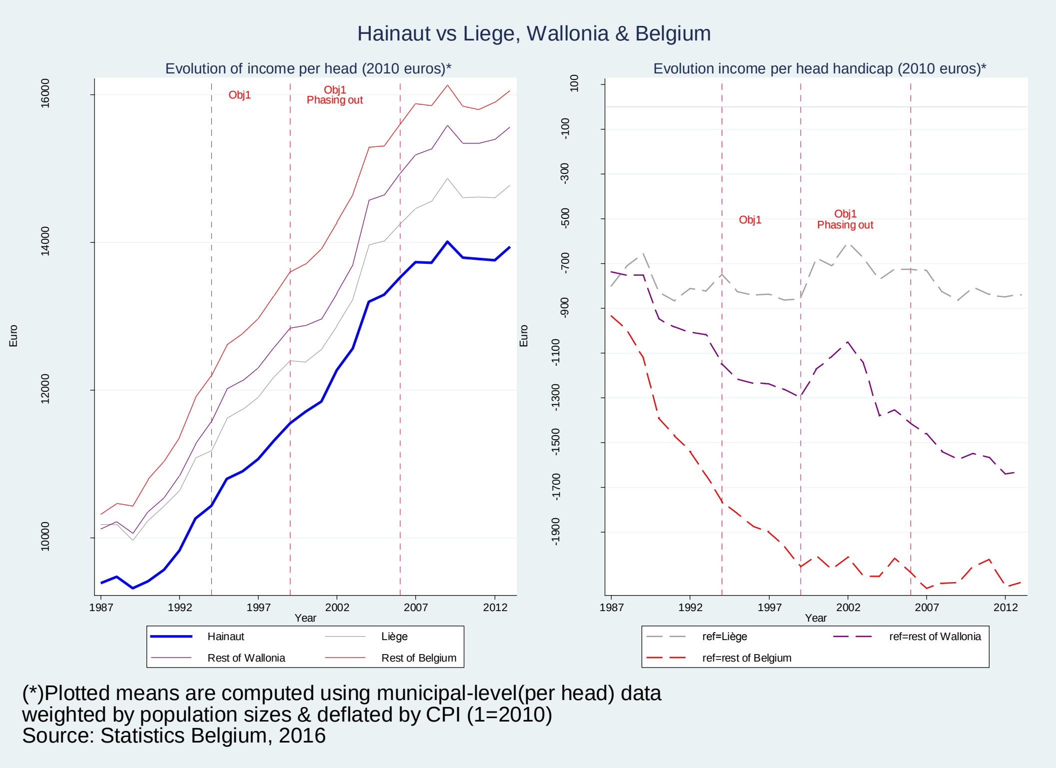
[9] Of social security contribution.

[10] Earnings for employment, capital and properties and also replacement earnings.

income at municipal level are amongst the oldest of Belgium' statistical apparatus. Also, taxable income is in essence an aggregate outcome variable; very close to what GDP per head captures. Using it as our main outcome variable means that we consider that the benefits of Objective 1 (whatever the precise project/programme or policy that it has financed) should ultimately show up in the sums of money earned by people residing in Hainaut (and on which they are taxed). Although some may argue in favour of other measures of outcomes (employment….) we tend to favour this one because it corresponds relatively well to the goal assigned by EU decision makers to Objective 1; but also because it is likely to capture the (monetary) spillovers of the programme (e.g. beyond net job creation or higher wages due to higher productivity (i.e. the direct benefits), an improved capacity to attract wealthier residents…).

Figure 4 (left panel) displays the evolution of income per head (in 2010 euros) for the treated vs the three control territories used in this paper. It confirms the income-level handicap of Hainaut (blue solid line) compare to the other Belgian provinces. Vertical bars help identify the calendar of implementation of Objective 1 with the initial 1994-1999 phase, followed by the "phasing out" from 2000 to 2006. The right panel of Figure 4 gives a first (purely descriptive) indication of what happened before, during and after Objective 1. The plotted dashed lines report the year-by-year evolution of the income-level difference (in 2010 euros) of Hainaut vs. each of the three control entities. These lines logically confirm the existence of an income-level handicap before Objective 1 ranging from 700 to more than 1,900 euros. More to the point in the context of this paper, they suggest the incom-level handicap was *not constant* before Objective 1, certainly when comparing Hainaut to the rest of Wallonia or the rest of Belgium. Another interesting feature visible on Figure 4 (right panel) is the continuing rise of Hainaut's income-level handicap (in constant euros) compare to these two entities, during and after Objective 1. The comparison with Liège rather suggests a stable income-level handicap. But one should abstain to jump to conclusions at this early stage of the analysis. At the very least, we should question the relevance of $Parallel_{[1]}$ – except maybe when using Liège as control – to assess Objective 1's true impact on income.

Figure 4 – Evolution of taxable income per head (2010 euros) in Hainaut municipalities (vs. Liège, rest of Wallonia, or rest of Belgium), 1997-2013



(*)Plotted means are computed using municipal-level(per head) data
weighted by population sizes & deflated by CPI (1=2010)
Source: Statistics Belgium, 2016

Table 1- Municipality count. Hainaut, Liège, rest of Belgium or rest of Wallonia

Rest of Belgium	520
Rest of Wallonia	193
Liège	84
Hainaut	**69**
Total	589

4. Econometric results

We first report the results for the canonical/two periods (i.e. before and after) $DD_{[1]}$ model. Remember that Objective 1 started in 1994. We thus take *t*=1993 as the most immediate year before the treatment was implemented.[11] The after-treatment years are $t+s$=2000 (immediately after the end of Objective 1) and 2007 (immediately after the end of the phasing-out period.

$$Y_{t+s} = \gamma + \gamma_{t+s} I_{t+s} + \gamma^{D} D + \gamma^{D}_{t+s} D.\ I_{t+s} \qquad [9.]$$

where t=1993 and $t+s$= 2000 or 2007

Results (Table 2) are mixed. Compare to Liège, the 1993 handicap was of 820 euros in 1993. In 2000, it was 177 euros smaller. And 91 euros smaller in 2007, just after end of the phasing out period. Compare to the rest of Wallonia, the handicap was of 1,018 euros in 1993, but it had risen by respectively 131 and 422 euros in 2000 and 2007. And compare to the rest of Belgium, the initial handicap was even larger (1,646 euros) and kept rising by 426 and 506 euros respectively at the horizon 2000 and 2007. And all these values are statistically significant the 1% threshold.

These estimates have a descriptive value; in the sense that they accurately describe the evolution of Hainaut's income per head handicap. It is much less certain, however, that they properly identify the impact of Objective 1. Remember that $DD_{[1]}$ is suitable to identify a treatment effect only if the $Parallel_{[1]}$ assumption holds. But we possess several pre-treatment points of observation in our data. And these can be used to compute $DD_{[1]}$ for a series of years *prior to* 1994. Results are plotted on Figure 5 (green solid lines). Using the rest of Belgium or the rest of Wallonia as control, we clearly conclude that Hainaut was not growing at the same rate. $DD_{[1]}$ estimates are indeed significantly negative for all the years before 1993. Even in comparison with Liège, we get that $DD_{[1]}$ is slightly negative over the 1989 and 1993 period. This represents a clear violation of the $Parallel_{[1]}$ assumption.

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[11] We tend to believe that the usual debate about anticipation-of-treatment effects is irrelevant here. Strictly speaking Hainaut was not Objective-1 eligible, as its GDP per head was above the 75% threshold. It only got retained by the Commission after intense lobbying. Thus until the last moment, there was a lot of uncertainty; meaning that economic agents could not reasonably anticipate the influx of money.

We thus need to go beyond $Parallel_{[1]}$ in order to say something relevant about the true impact of Objective 1. Interestingly, as we possess many pre-treatment periods, we are able to assess the plausibility of $Parallel_{[2]}$ or $Parallel_{[3]}$ by estimating $DD_{[2]}$ or even $DD_{[3]}$, again prior to Objective 1's inception. $Parallel_{[2]}$ consists of assuming that Hainaut and its controls where experiencing different accelerations/growth rates before 1994; but that the latter difference was stable/time-invariant. We are able to test the plausibility of that assumption by estimating $DD_{[2]}$ for the pre-treatment years; and verifying that is it close to zero. Figure 5 (red dashed lines) suggests thas was the case, at least between 1988 and 1993, for each of the three controls. The tentative conclusion is that $Parallel_{[2]}$ is a much more realistic description of the relative dynamics of Hainaut's income per head in the absence of Objective 1. And logically, the next steps of our econometric analysis will rest on $DD_{[2]}$/ $Parallel_{[2]}$.

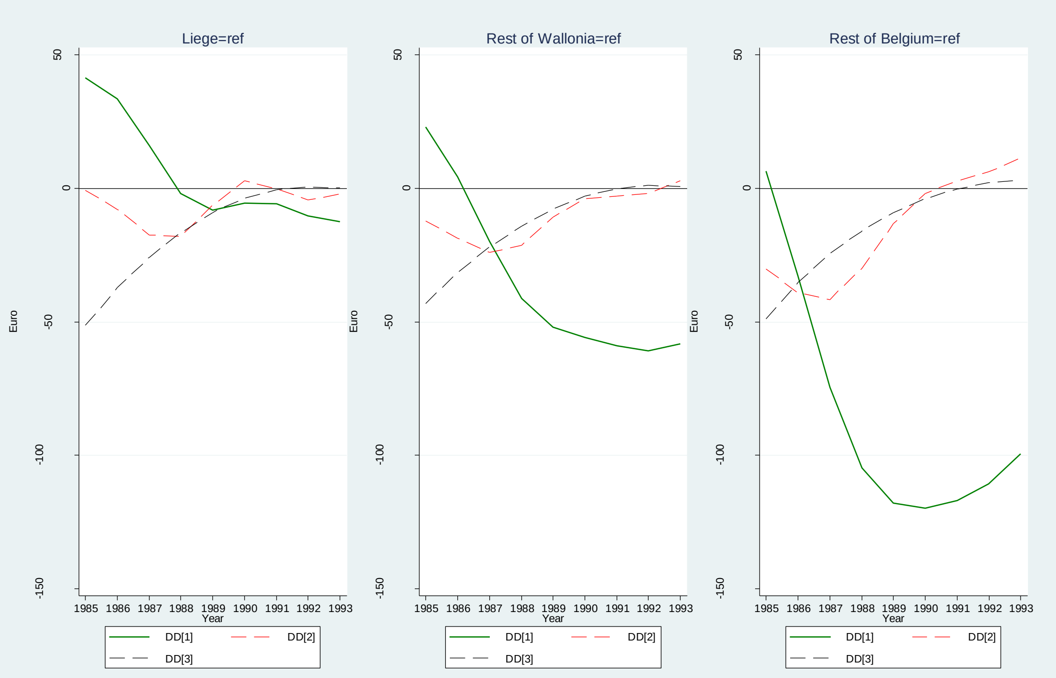
The key results are on display on Figure 6. And the underlying numbers can be found in Table 3. On Figure 6, we confront the $DD_{[1]}^{t+s}$ and $DD_{[2]}^{t+s}$ estimates, where t=1993 and $t+s$=1994 to 2013 (from 1 to 20 years after the start of Objective 1). All of them stress the quite dramatic change of perspective induced by the shift from $DD_{[1]}^{t+s}$ to $DD_{[2]}^{t+s}$; mostly when comparing Hainaut to the rest of Wallonia and the rest of Belgium. On the lower part of Figure 6, results are normalized by the average taxable income per head of the whole of Belgium. Qualitatively, the results are unaffected. In particula,r $DD_{[2]}^{t+s}$ estimates suggest that Objective 1 has had a *positive* impact on the acceleration/growth rate handicap that Hainaut was suffering from before 1994. That positive effect is particularly visible beyond 1999, in comparison with Liège and the rest of Wallonia. In the absence of this correction, the rise of the income-level handicap (captured by $DD_{[1]}^{t+s}$) would have been larger. Over the year 2000 horizon (Table 3), Hainaut experienced a rise of its income-level handicap compared to the rest of Belgium of 426.1 euros. What $DD_{[2]}^{t+s}$ = 491.9 euros means is that in the absence of an acceleration/growth rate handicap positive correction; that rise would have been of 426.1 + 491.9 euros.

Table 2 - Canonical DD[1] estimation of Objective 1's impact on taxable income per head (in 2010 euros), t=1993, t+s=2000/2007 using province of Liège, rest of Belgium or rest of Wallonia as control entity

	Liege 2000	**Liege 2007**	**r.of Wall. 2000**	**r.of Wall. 2007**	**r.of Bel. 2000**	**r.of Bel. 2007**
γ_{t+s}	1341.66^{***}	3378.74^{***}	1650.10^{***}	3912.85^{***}	1944.82^{***}	3976.90^{***}
	(1.729)	(1.913)	(1.701)	(1.754)	(0.847)	(0.900)
γ^D	-820.70^{***}	-820.70^{***}	-1018.05^{***}	-1018.05^{***}	-1646.08^{***}	-1646.08^{***}
	(1.348)	(1.348)	(1.404)	(1.404)	(1.021)	(1.021)
γ^D_{t+s}	177.02^{***}	91.41^{***}	-131.42^{***}	-442.70^{***}	-426.15^{***}	-506.75^{***}
	(2.262)	(2.461)	(2.240)	(2.340)	(1.686)	(1.791)
γ	11076.57^{***}	11076.57^{***}	11273.91^{***}	11273.91^{***}	11901.94^{***}	11901.94^{***}
	(1.036)	(1.036)	(1.108)	(1.108)	(0.547)	(0.547)
Rsq	0.31	0.64	0.28	0.60	0.30	0.55
$DD_{[1]} = \gamma^D_{t+s}$	177.02	91.41	-131.42	-442.70	-426.15	-506.75
$p\_DD_{[1]}=0$	0.000	0.000	0.000	0.000	0.000	0.000

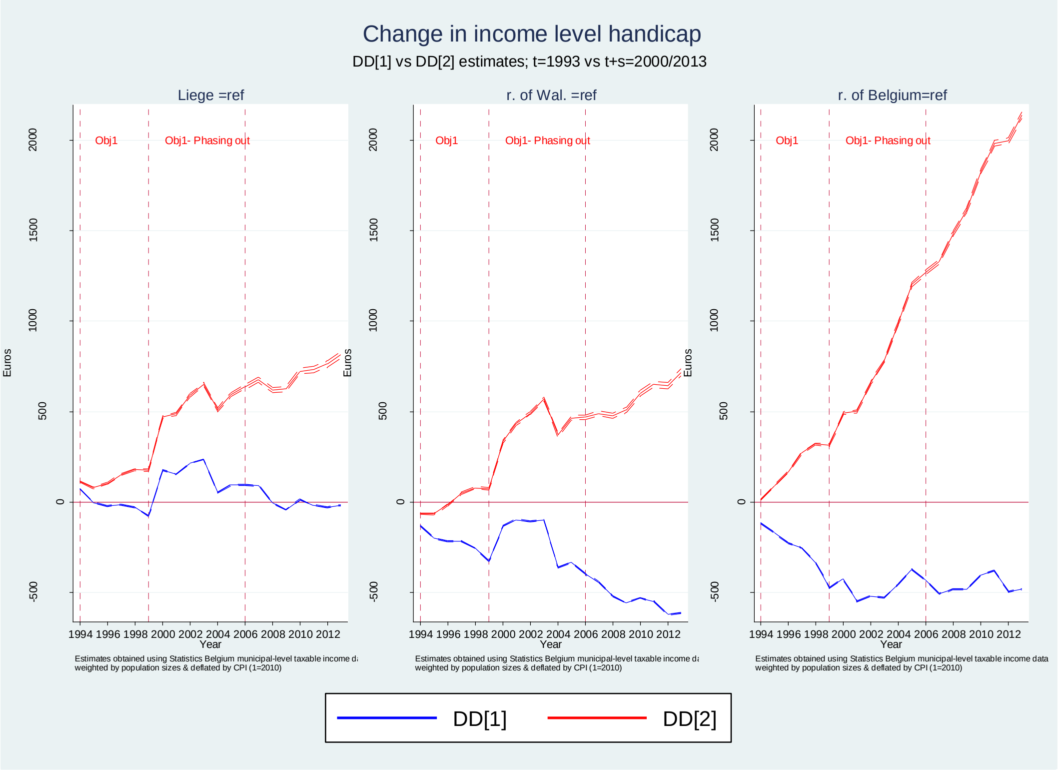
Standard errors in parentheses
Estimates obtained using Statistics Belgium municipal-level(per head) taxable income data, weighted by population sizes & deflated by CPI (1=2010)
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 5- Assessing Parallel$_{[1]}$ vs Parallel$_{[2]}$ and Parallel$_{[3]}$ before the start of Objective 1 (t=1985 to 1993)



(*)Plotted means are computed using municipal-level(per head) data
weighted by population sizes & deflated by CPI (1=2010)
Source: Statistics Belgium, 2016

Figure 6 – Estimates of Objective 1's impact on the level of taxable income per head (in 2010 euros), s-periods ahead of t=1993; $DD_{[2]}^{t+s}/Parallel_{[2]}$ *vs* $DD_{[1]}^{t+s}/Parallel_{[1]}$, *t+s=1994 to 2013*



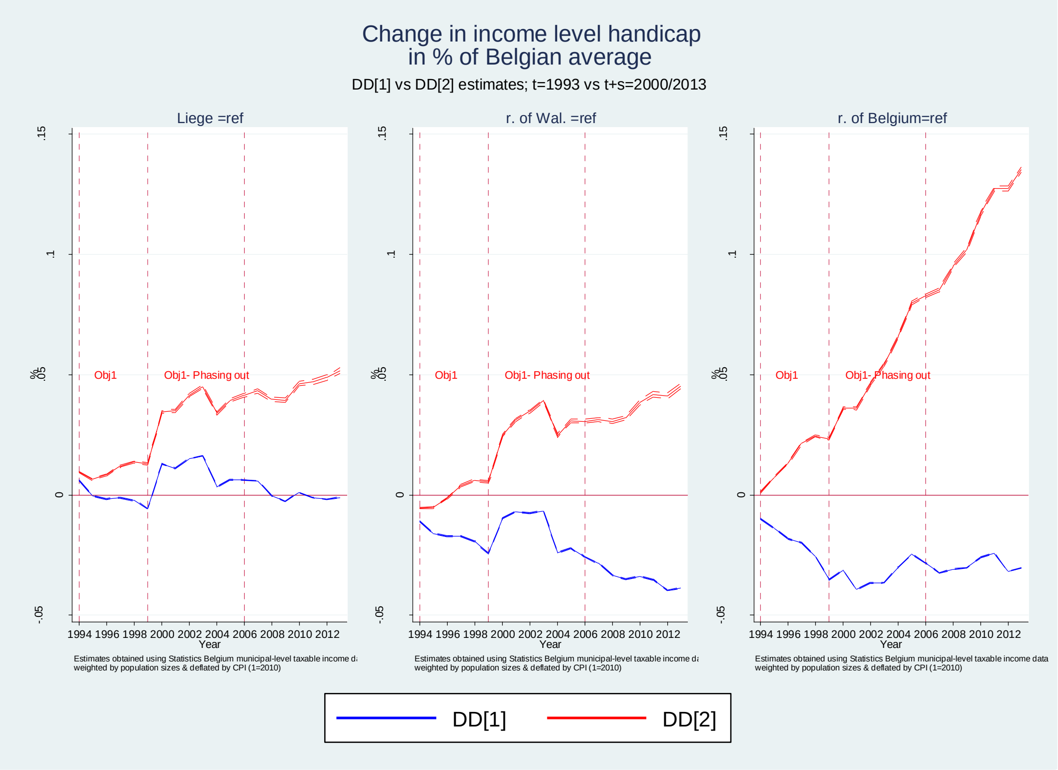


Table 3 - Estimates of Objective 1's impact on the level of taxable income per head (in 2010 euros), s-periods ahead of t=1993; $DD_{[2]}^{t+s}/Parallel_{[2]}$ *vs* $DD_{[1]}^{t+s}/Parallel_{[1]}$, *t+s=1994 to 2013*

		In 2010 euros						**In 2010 euros relative to Belgium average income**					
t+s	***s***	**Control=Liège**		**Control=rest of Wallonia**		**Control=rest of Belgium**		**Control=Liège**		**Control=rest of Wallonia**		**Control=rest of Belgium**	
		$DD_{[1]}$	$DD_{[2]}$	$DD_{[1]}$	$DD_{[2]}$	$DD_{[1]}$	$DD_{[2]}$	$DD_{[1]}$	$DD_{[2]}$	$DD_{[1]}$	$DD_{[2]}$	$DD_{[1]}$	$DD_{[2]}$
1994	1	72.2	113.8	-130.8	-64.2	-118.2	13.0	0.60%	0.95%	-0.99%	0.11%	-1.09%	-0.54%
1995	2	-3.8	79.6	-198.7	-65.5	-171.6	90.7	-0.03%	0.64%	-1.39%	0.73%	-1.60%	-0.53%
1996	3	-21.1	103.8	-215.4	-15.7	-227.4	166.1	-0.17%	0.83%	-1.81%	1.33%	-1.72%	-0.13%
1997	4	-14.5	152.1	-217.3	49.0	-253.2	271.4	-0.11%	1.20%	-1.99%	2.13%	-1.71%	0.38%
1998	5	-30.0	178.3	-254.0	78.9	-335.2	320.5	-0.23%	1.36%	-2.56%	2.45%	-1.94%	0.60%
1999	6	-75.0	174.9	-325.9	73.6	-473.2	313.7	-0.56%	1.30%	-3.52%	2.34%	-2.43%	0.55%
2000[a]	**7**	**177.0**	**468.6**	**-131.4**	**334.6**	**-426.1**	**491.9**	**1.30%**	**3.45%**	**-3.14%**	**3.62%**	**-0.97%**	**2.46%**
2001	8	153.6	486.8	-97.8	434.8	-547.9	501.3	1.10%	3.50%	-3.94%	3.60%	-0.70%	3.13%
2002	9	215.1	590.0	-106.3	492.9	-519.7	660.7	1.51%	4.15%	-3.66%	4.65%	-0.75%	3.47%
2003	10	235.0	651.5	-97.9	567.9	-528.3	783.2	1.62%	4.50%	-3.65%	5.41%	-0.68%	3.93%
2004	11	51.2	509.4	-361.9	370.4	-452.5	990.2	0.34%	3.39%	-3.01%	6.59%	-2.41%	2.46%
2005	12	94.0	593.9	-334.6	464.3	-371.8	1202.0	0.62%	3.94%	-2.47%	7.98%	-2.22%	3.08%
2006	13	94.9	636.4	-395.9	469.6	-433.3	1271.6	0.62%	4.15%	-2.82%	8.29%	-2.58%	3.06%
2007[b]	**14**	**91.4**	**674.6**	**-442.7**	**489.4**	**-506.8**	**1329.3**	**0.59%**	**4.32%**	**-3.24%**	**8.51%**	**-2.83%**	**3.13%**
2008	15	-4.8	620.0	-520.9	477.8	-482.0	1485.3	-0.03%	3.98%	-3.09%	9.53%	-3.34%	3.06%
2009	16	-41.2	625.2	-556.1	509.1	-481.1	1617.3	-0.26%	3.94%	-3.03%	10.19%	-3.50%	3.21%
2010	17	14.8	722.9	-529.6	602.3	-405.0	1824.5	0.09%	4.63%	-2.60%	11.70%	-3.39%	3.86%
2011	18	-17.2	732.6	-547.6	650.8	-378.0	1982.7	-0.11%	4.71%	-2.43%	12.75%	-3.52%	4.18%
2012	19	-28.4	763.0	-620.9	644.1	-497.0	1994.8	-0.18%	4.88%	-3.18%	12.76%	-3.97%	4.12%
2013	20	-17.1	816.0	-612.5	719.1	-480.8	2142.2	-0.11%	5.16%	-3.04%	13.55%	-3.87%	4.55%

Estimates obtained using Statistics Belgium municipal-level taxable income data, weighted by population sizes & deflated by CPI (1=2010)

[a]: End of (main phase) of Objective 1-Hainaut

[b]: End of phasing out

Concluding remarks

The traditional difference-in-differences $DD_{[1]}$ model – and the parallel-paths/$Parallel_{[1]}$ assumption on which it rests – seems to be particularly irrelevant in the case of Objective1-Hainaut; and perhaps also for other EU rust-belt regions that became eligible to Ojective1. Remember that Hainaut got selected by the EU expressly because "*it was suffering from a substantial deterioration of its economic and social situation*". This statement hints at a development path that was not parallel to that of other EU or Belgian regions. We show in this paper that this was indeed the case before the introduction of Objective 1. And this is something that disqualify $DD_{[1]}$ to be a proper treatment-effect identification strategy. From a methodological point of view, we also show that if data contains more than one point of observation before treatment, it is very easy to drop $Parallel_{[1]}$ – i.e. the parallel-paths assumption on which $DD_{[1]}$ is based – and implement $DD_{[2]}/Parallel_{[2]}$; or even models allowing for higher degree of parallelism. In a nutshell, $Parallel_{[2]}$ means *i)* allowing for (time-invariant) acceleration/growth rate differences in the absence of treatment and *ii)* ascribing to the treatment (the outcome effect of) any change of the ex-ante acceleration difference. The paper also shows that the estimation of treatment outcome under $Parallel_{[2]}$, or higher degree of parallelism, can be achieved via OLS applied to a generalized version the canonical linear *DD* equation, containing time/treatment interaction terms.

This being said, as our Hainaut-Objective 1 results clearly show, $DD_{[2]}/Parallel_{[2]}$ is much more likely to lead to the conclusion that the treatment has been effective: all it takes is a small reduction of the pre-treatment acceleration/growth rate handicap to conclude that treatment has generate gains. And in the case of Hainaut, we show that this can happen against a background of a steadily rising income-*level* handicap; which something that most people would probably interpret as an absence of convergence.

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